

Final Report

Shipboard Tests of the

Bio-UV

Ballast Water Treatment System

(Filtration and UV)

for Type Approval according to Regulation D-2

and the relevant IMO Guideline (G8)

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**Final report of the shipboard tests of the
Bio-UV BIO-SEA
Ballast Water Treatment System
(Filtration and UV)
for Type Approval according to Regulation D-2
and the relevant IMO Guideline (G8)**

(August 2012 – February 2013)

Shipboard tests onboard MV *Marfret Sormiou*

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1. Introduction

Three shipboard test cycles were conducted to test the performance of the BIO-SEA ballast water treatment system (filtration and UV). This treatment system was developed by Bio-UV, Lunel, France. In total three voyages were undertaken on the container vessel MV *Marfret Sormiou* and the voyages occurred between August 2012 and February 2013. The vessel details and the dimensions of both test tanks are shown in Table 1.

Table 1. Main dimensions of the test vessel and test tank details.

Vessel name	Marfret Sormiou
IMO number	9231157
Flag	Luxembourg
Class	Bureau Veritas
Vessel type	container
Length overall	210 m
Gross Tonnage	27093 t
Total ballast water capacity	9381 m ³
Number of ballast tanks	16
Number of ballast pumps	2
Capacity of ballast pump	500 m ³ /h
Number of ballast water treatment systems installed	1
Treatment capacity for this vessel	500 m ³ /h
Control tank	N3 D.B.W.B.T.
Control tank capacity	689.5 m ³
Treated tank	N4 D.B.W.B.T.
Treated tank capacity	687,6 m ³

The test ship operates on a regular route calling for ports in Europe, USA east coast, Australia and New Zealand.

The BWMS installed on board had a treatment rated capacity (TRC) of 500 m³/h. The treatment system was installed in 2012, and it is fully implemented into the ballast water system of the vessel.

During all G8 test cycles both the control tank and the treated ballast tanks, were operated in sequence. The tanks were filled and emptied as much as possible.

All samples were taken almost over the entire ballast water uptake and discharge time, i.e. during the entire pumping event. This approach most likely resulted in a more accurate organism density assessment in comparison to taking sequential sub-samples during parts of the ballast water pumping operation (e.g. in the beginning, middle and

end of the pumping time). By sampling with the sequential method organism rich water layers of the tank may be missed during the sampling event.

For the three test cycles the ballast water was taken up in the following regions:

- Test cycle 1, uptake Kingston, Jamaica, discharge off Manzanillo, Panama;
- Test cycle 2, uptake Rotterdam, The Netherlands, discharge Le Havre, France; and
- Test cycle 3, uptake Melbourne, Australia, discharge en-route to Napier, New Zealand.

The holding time of the ballast water in the tank between uptake and discharge was between ca. 36 and 60 hours (Fig. 1).

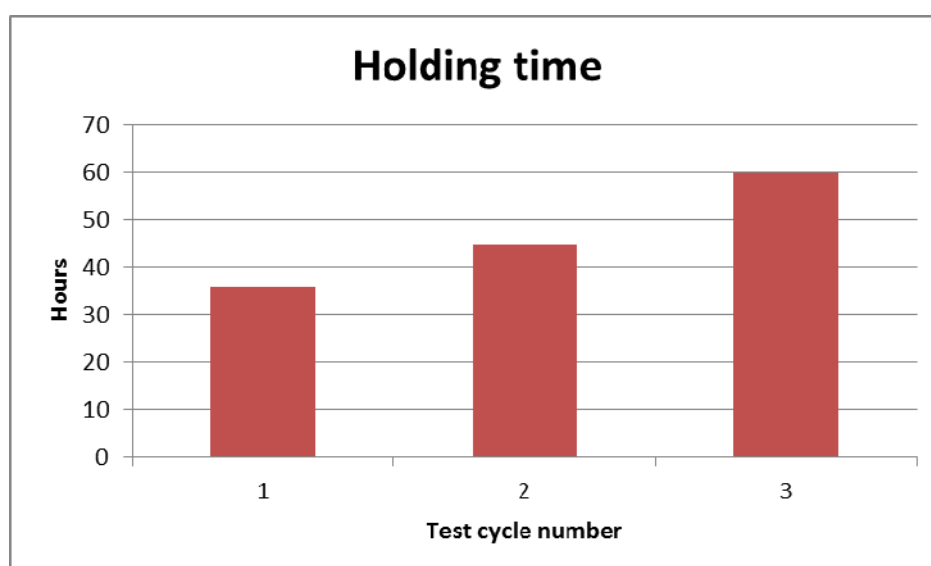


Figure 1. Approximate in-tank holding times of the ballast water between uptake and discharge during all three test cycles.

During all test cycles all samples were taken by sampling team members of GoConsult, Hamburg, Germany.

The chain of custody was guaranteed as the samples to be delivered to the land-based laboratories were transported by GoConsult staff so that no external manipulation was possible. However, one exception of this rule occurred for the last sampling voyage. Here, the uptake samples were taken in Melbourne, Australia and to avoid the phytoplankton samples to become to a critical “age” they were not kept until the GoConsult sampling team came back after the voyage ended in Napier, New Zealand, but the samples were sent with a professional courier directly from Melbourne to NIOZ for subsequent analysis.

2. Sampling scenario

The agreed on board sampling protocol (Gollasch & Ceresola 2012) shows that multiple HydroBios ballast water sampling kits were used in parallel during each test cycle. The samples were processed on board as much as possible immediately after the sampling event ended:

- plankton organisms 50 micron and above in minimum dimension were analysed directly after sampling.
- the sample processing of the indicator microbes *E. coli* and *Enterococci* was also conducted directly after sampling and the bacteria incubation time to document colony forming units as required by IMO G8 was completed on land when needed.
- Cholera bacteria samples were prepared for later analysis by IBEN, Bremerhaven, Germany. They were transported either by a portable incubator or in a Styrofoam box with a heating element.
- the samples for plankton less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension and the phytoplankton below 10 micron in minimum dimension were prepared directly after sampling. These samples were stored in a fridge, were transported in a Styrofoam box with a cooling element and the samples were analysed by NIOZ, Texel, the Netherlands.

Procedures for sample processing as outlined in the test protocol (Gollasch & Ceresola 2012) were followed. The protocol was prepared in line with the most up-to-date version of the IMO Guideline G8 *Guidelines for the Approval of Ballast Water Management Systems* (IMO, 2008) and was agreed by the Administration who is involved in the certification of this ballast water treatment system. The agreed number of samples and their volumes for one test cycle according to the IMO G8 Guidelines are given in Table 2.

Table 2. Number of samples and their volumes for one test cycle according to G8. The paragraph numbers referenced refer to paragraphs of the IMO G8 Guidelines (IMO, 2008).

Sample purpose	Treated tank	Control tank	
	discharge (para 2.2.2.6.2 and 2.2.2.6.3)	uptake (para 2.2.2.6.1, 2.2.2.6.3 and 2.2.2.9)	discharge (para 2.2.2.6.1 and 2.2.2.6.3)
Environmental parameters ¹	1 sample (not required in G8)	1 sample	1 sample (not required in G8)
>50 µm	3 x >1000 L	1 x >1000 L	1 x >1000 L
<50 to >10 µm	3 x >1 L	1 x >1 L	1 x >1 L
Bacteriae	3 x >500 ml	1 x >500 ml	1 x >500 ml (not required in G8)

¹ Temperature, salinity, total suspended solids and particulate organic carbon, see G8, Annex, Part 2, paragraph 2.2.2.9

The following samples were taken and processed in addition to the requirements of IMO Guideline G8:

- Analysis of environmental and biological parameters of the uptake treated water;
- Analysis of environmental parameters of the discharged treated water;
- Analysis of environmental parameters of the discharged control water;
- Analysis of bacteriae of the discharged control water; and
- Analysis of phytoplankton organisms below 10 micron in minimum dimension.

3. Results

Results of the measured environmental parameters and the biological analysis of the samples are shown in the following tables. As stated above more environmental parameters and more biological analysis than required by the IMO G8 Guidelines were conducted (IMO, 2008).

Environmental parameters

The sample processing of the environmental parameters resulted in values to be expected in the ballast water uptake regions.

Biological results

For all tested organism groups and during all tests of the treated water upon discharge, the results show that the water treated with the BIO-SEA ballast water treatment system complied with the Ballast Water Performance Standards (Regulation D-2) of the IMO Ballast Water Management Convention (IMO 2004).

Further, the minimum intake organism concentrations as stated in the IMO G8 Guidelines were met in all test cycles (IMO, G8).

During all test cycles and for all organism groups the D-2 standard was met at discharge of the treated water. This includes the phytoplankton organisms below 10 micron in minimum dimension which were processed in addition to the requirements of IMO.

Test Cycle Report, Test Cycle 1

Date and time for ballast water **uptake**: 02.08.2012, 17.52 to 20.33h

Position of ship during start of ballast water uptake:

- in Port of Kingston, Jamaica.
- Water depth ca. 14 m.

Date and time for ballast water **discharge**: 04.08.2012, 06.08 to 09.41

Holding time of ballast water between uptake and discharge: approximately 36 hrs.

Weather conditions during the test: good.

Table 3. Results of Test Cycle 1.

(nd = not detectable).

Parameter	Unit	Uptake water			Discharge water						
		control	IMO	before treatment	Control	IMO	Treated			aver. #1-#3	IMO
							# 1	# 2	# 3		
Temperature	°C	30.7	-	30.4	28.5	-	28.8	28.8	28.8	-	-
Salinity	Psu	35.4	-	35.5	35.1	-	35.2	35.2	35.2	-	-
POC *	mg/l	11.0	-	12.5	14.0	-	10.6	9.0	10.2	-	-
TSS *	mg/l	21.0	-	23.3	30.8	-	20.0	18.4	19.4	-	-
UV-T *	%	87.5	-	77.4	86.3	-	92.4	92.3	90.6	-	-
Sample vol. >50 µm	Litres	1521	>1000	1593	2086	>1000	1959	1924	1933	-	>1000
Sample vol. 50-10 µm	Litres	5	>1	5	6	>1	6	6	6	-	>1
Sample vol. bacteria	Litres	1	>0.5	1	1	-	1	1	1	-	>0,5
Organisms >50 µm	org./1m³	17594	>90	9517	2339	>10	7.9	4.0	6.0	5.9	<10
Organisms 10-50 µm *	org./1ml	3666	>90	6056	5137	>10	nd	nd	nd	nd	<10
Organisms 5-10 µm *	org./1ml	4737	-	8632	3260	-	nd	nd	nd	nd	-
<i>Escherichia coli</i>	cfu/100ml	39	-	80	10	-	nd	nd	nd	nd	<250
Intestinal <i>Enterococci</i>	cfu/100ml	130	-	140	160	-	10	7	9	8.7	<100
<i>Vibrio cholera</i> **	cfu/100ml	nd	-	nd	nd	-	nd	nd	nd	nd	<1

* Samples analysed at NIOZ, Texel. ** Samples analysed at IBEN, Bremerhaven.

Test Cycle Report, Test Cycle 2

Date and time for ballast water **uptake**: 07.10.2012, 11.07 to 13.20h

Position of ship during start of ballast water uptake:

- Port of Rotterdam, the Netherlands.
- Water depth ca. 14 m.

Date and time for ballast water **discharge**: 09.10.2012, 09.58 to 12.41h

Holding time of ballast water between uptake and discharge: approximately 45 hrs.

Weather conditions during the test: good.

Table 4. Results of Test Cycle 2.

(nd = not detectable).

Parameter	Unit	Uptake water			Discharge water						
		control	IMO	before treatment	Control	IMO	Treated			aver. #1-#3	IMO
							# 1	# 2	# 3		
Temperature	°C	15.4	-	16.2	16.3	-	16.3	16.3	16.3	-	-
Salinity	Psu	2.2	-	2.1	5.2	-	5.0	5.0	5.0	-	-
POC *	mg/l	5.0	-	5.0	4.0	-	6.0	4.6	4.6	-	-
TSS *	mg/l	7.0	-	6.8	5.6	-	9.4	7.4	7.4	-	-
UV-T *	%	80.6	-	79.6	81.4	-	82.4	82.4	81.5	-	-
Sample vol. >50 µm	Litres	1532	>1000	1507	1773	>1000	1590	1588	1600	-	>1000
Sample vol. 50-10 µm	Litres	6	>1	6	6	>1	6	6	6	-	>1
Sample vol. bacteria	Litres	1	>0,5	1	1	-	1	1	1	-	>0,5
Organisms >50µm	org./1m³	4984	>90	3980	4377	>10	12.1	4.8	7.2	8.1	<10
Organisms 10-50µm *	org./1ml	708	>90	678	555	>10	nd	nd	nd	nd	<10
Organisms 5-10 µm *	org./1ml	97	-	79	69	-	nd	nd	nd	nd	
<i>Escherichia coli</i>	cfu/100ml	320	-	240	180	-	nd	nd	nd	nd	<250
Intestinal <i>Enterococci</i>	cfu/100ml	90	-	130	70	-	30	40	30	33.3	<100
<i>Vibrio cholerae</i> **	cfu/100ml	nd	-	nd	nd	-	nd	nd	nd	nd	<1

* Samples analysed at NIOZ, Texel. ** Samples analysed at IBEN, Bremerhaven.

Test Cycle Report, Test Cycle 3

Date and time for ballast water **uptake**: 14.02.2013, 02.33 to 05.43h

Position of ship during start of ballast water uptake:

- Port of Melbourne, Australia.
- Water depth ca. 14 m.

Date and time for ballast water **discharge**: 16.02.2013, 14.27 to 17.32h

Holding time of ballast water between uptake and discharge: approximately 60 hrs.

Weather conditions during the test: good.

Table 5. Results of Test Cycle 3.

(nd = not detectable).

Parameter	Unit	Uptake water			Discharge water						
		control	IMO	before treatment	Control	IMO	Treated			aver. #1-#3	IMO
							# 1	# 2	# 3		
Temperature	°C	22.1	-	22.2	20.0	-	20.3	20.3	20.3	-	-
Salinity	Psu	33.5	-	33.6	33.7	-	34.0	34.0	34.0	-	-
POC *	mg/l	11.5	-	10.8	11.3	-	16.7	17.0	16.3	-	-
TSS *	mg/l	33.3	-	35.0	28.5	-	59.3	62.7	45.3	-	-
UV-T *	%	81.0		79.9	88.4	-	76.7	74.5	80.4	-	-
Sample vol. >50 µm	Litres	1731	>1000	1593	1543	>1000	1514	1527	1542	-	>1000
Sample vol. 50-10 µm	Litres	6	>1	6	6	>1	6	6	6	-	>1
Sample vol. bacteria	Litres	1	>0,5	1	1	-	1	1	1	-	>0,5
Organisms >50µm	org./1m³	24620	>90	22107	19821	>10	7.6	7.6	2.5	5.9	<10
Organisms 10-50µm *	org./1ml	3164	>90	5251	1694	>10	nd	nd	nd	nd	<10
Organisms 5-10 µm *	org./1ml	464	-	718	279	-	nd	nd	nd	nd	-
<i>Escherichia coli</i>	cfu/100ml	21	-	25	2	-	nd	nd	nd	nd	<250
Intestinal <i>Enterococci</i>	cfu/100ml	80	-	110	60	-	nd	40	10	16.7	<100
<i>Vibrio cholerae</i> **	cfu/100ml	nd	-	nd	nd	-	nd	nd	nd	nd	<1

* Samples analysed at NIOZ, Texel. ** Samples analysed at IBEN, Bremerhaven.

4. Discussion of the results

The BIO-SEA ballast water treatment system was tested during three test voyages and on each voyage one test cycle was completed (August 2012 to February 2013).

The tests were conducted in different seasons and different environmental water conditions. As a consequence the organism concentrations in the uptake water were different in all test voyages.

Sample taking, sample processing and sample forwarding for all three test voyages was always conducted as outlined in the agreed sampling protocol (Gollasch & Ceresola 2012). As an exception, the uptake phytoplankton samples from the last voyage, which was sampled in Melbourne, Australia, were shipped to the analytical laboratory NIOZ directly by a commercial courier service.

5. Test validity

Samples

All agreed samples were taken to document the abiotic and biotic water conditions during the tests. Additional samples were taken and all samples were analysed for more parameters as required by the IMO G8 Guidelines (see above). The minimum water volumes of all sample types, as stated in the IMO G8 Guidelines, were met.

Biology

The required minimum organism intake concentrations to challenge the treatment system exceeded the numbers as stated in the IMO G8 Guidelines in all test cycles.

For all test cycles the treated water at discharge met the organism concentration limits for a valid test as stated in Regulation D-2 of the IMO Ballast Water Management Convention (IMO 2004). However, the organisms 50 micron and above in minimum dimension were documented in concentrations above 5 living individuals per cubic metre in the treated water on discharge during all test cycles. In test cycle 1 the average of all replicate treated discharge water samples contained 5.9 living individuals, in test cycle 2 in average 8.1 living individuals and in test cycle 3 in average 5.9 living individuals were found. The average number of the organisms 50 micron and above in minimum dimension of all three test cycles was 6.6 living individuals per cubic metre in the treated water on discharge.

It should be noted that the phytoplankton organisms in the size class below 10 micron in minimum dimension were also measured and no living phytoplankton was found in the treated water at discharge.

References

Gollasch, S. & Ceresola, C. 2012. Quality Management Plan and Quality Assurance Project Plan for Shipboard Tests of the Bio-UV Ballast Water Management System. Version 3, 15.06.2012, 58 pp.

IMO 2004. International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004. International Maritime Organization, 13 February 2004. 36 pp.

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